Description

Lithography objective and projection exposure system having at least one such lithography objective

[0001] The invention relates to an optical imaging system for a microlithography projection exposure system for imaging an object field arranged in an object plane of the imaging system into an image field arranged in an image plane of the imaging system, and to a microlithography projection exposure system comprising at least one such optical imaging system.

[0002] Microlithography projection exposure systems are used for the microlithographic production of semiconductor components and other finely structured subassemblies. A projection exposure system has an illumination system and a projection objective downstream of the illumination system. The task of the illumination system is to prepare the light of a primary light source, for example a laser, such that a mask (reticle) that is arranged in an exit plane of the illumination system and has a pattern to be imaged can be illuminated in a way that can be prescribed in definite terms. The mask is located in the object plane of the downstream projection objective whose task it is to image the pattern of the mask with the highest possible resolution onto an object coated with a photosensitive layer, for example a semiconductor wafer coated with a photoresist layer, with the highest possible resolution.

[0003] A projection objective for microlithography is a complex diffraction-limited optical imaging system comprising a plurality of lenses whose number and diameter typically increase the higher the requirements made of the resolving capability and of the optical correction. Modern projection objectives that are designed for resolving typical structure sizes of 100 nm or below and operate with ultraviolet light from the deep ultraviolet (DUV) region frequently have more than twenty lenses that are further supplemented by at least one imaging concave mirror in the case of catadioptric

systems.

[0004] At least one optical imaging system is likewise normally provided inside the illumination system in order to image an illumination field arranged in an intermediate field plane of the illumination system into the exit plane of the illumination system. An essential task of such an imaging system is to adapt the properties of the illumination light with regard to field size and beam path to the entrance-end requirements of the downstream projection objective. The setting of the telecentricity of the illumination light plays an essential role here. Such imaging systems are frequently denoted as relay objectives. If the object is used to image an intermediate field plane, equipped with a reticle masking device (REMA), of the illumination system into the exit plane of the illumination system or onto the reticle, the designation REMA objective is also used. These imaging systems also have a complex design comprising a plurality of lenses, which in some cases can have larger diameters.

[0005] Attempts have already been made for some time to achieve a more advantageous design of the imaging systems mentioned at the beginning by using aspheric surfaces (aspheres). An aspheric surface is an optical surface that is used to reflect or refract a light bundle and is neither spherical nor flat. It is known that aspheric surfaces produce additional degrees of freedom in the possibilities of correction that can be used for an improved optical correction and/or for a reduction in the number of surfaces, and/or in order to provide particular optical properties.

[0006] Patent US 4,906,080 exhibits a projection exposure system comprising an illumination system and a downstream projection objective. In order to adapt the light provided by the illumination system to the projection objective, the illumination system includes an imaging system having at least one aspheric surface that is calculated such that the principal ray angles of the radiation output by the illumination system substantially correspond to the principal ray angles of the downstream projection objective. In order to

ensure this adaptation to the telecentricity requirements of the projection objective, in one embodiment the last lens surface facing the exit plane or image plane of the imaging system is an aspheric surface whose surface

5   form substantially determines the ray angle adaptation.

[0007] Patent application EP 1 316 832 (corresponding to WO 02/14924) exhibits a relay objective for an illumination system of a projection expo- sure system in which in order to reduce the number of lenses and to re-

10   duce weight while retaining its optical properties, a number of aspheric sur- faces are provided, at least one of the aspheres being arranged in the vi- cinity of the object plane or in the vicinity of the image plane, that is to say in the vicinity of a field plane.

15   [0008] Patent application US 2002/0171944 A1 exhibits an illumination sys- tem for a projection exposure system in which a relay objective is provided that is subdivided into three lens groups. A first lens group closest to the object plane has a negative lens with a concave surface pointing toward the object plane, a second lens group with a positive lens, and a third lens

20   group. At least one of the lens surfaces in the first lens group is aspheric.

[0009] German patent application DE 196 53 983 (corresponding to US 6,366,410) exhibits a REMA objective where the use of fewer aspheric surfaces succeeds in reducing the number of the interfaces inside the sys-

25   tem that lead to reflection losses, and in reducing the glass path inside the system that determines the absorption by comparison to the prior art such that a substantially improved transmission efficiency is achieved. One lens surface is respectively aspheric in the case of the aspherized lenses. In some embodiments, aspheric surfaces are arranged both in the vicinity of a

30   pupil plane of the imaging system and in the vicinity of the object plane and/or the image plane.

[0010] Patent EP 0 869 383 B1 exhibits a double-focusing catadioptric pro- jection objective with an intermediate image where a lens with an aspheric

lens surface is arranged in the vicinity of a field plane, and a lens with an aspheric lens surface is arranged at a vast distance from a field plane in the vicinity of a pupil plane. The aim of using these aspheric lenses is to be able to correct the distortion and the aspherical aberration simultaneously without other aberrations being disadvantageously influenced.

[0011] European patent application EP 1 079 253 (corresponding to WO 99/52004) exhibits catadioptric projection objectives for a wavelength region of less than 180 nm in the case of which four or more aspheric surfaces are provided for supporting the optical correction. Because of the high number of aspheres, the mutually facing lens surfaces of adjacent lenses are aspheric surfaces at a number of points in the case of some embodiments.

[0012] Patent application US 2003/0030916 A1 exhibits various refractive projection objectives that are designed as three-belly systems with three bellies and two waists lying therebetween, and have a plurality of aspheres. The aspheric surfaces are concentrated in the waist regions, four consecutive aspheres being provided in the vicinity of the waist in one embodiment.

[0013] EP 0 851 304 A2 discloses the adjacent arrangement of aspheric lens surfaces of adjacent lenses in a projection objective. The mutually facing, aspheric surfaces are positioned in the region of a pupil plane of the projection objective, and are not rotationally symmetrical. They are mounted such that they can be displaced relative to one another in a radial direction. The difference between the mutually facing aspheric surfaces, and thus the combined action of the aspheric surfaces, is varied by the relative displacement. The aim thereby is to be able to set the optical imaging properties of the projection objective in a variable fashion.

[0014] The international patent application WO 01/50171 (corresponding to EP 1 242 843) exhibits refractive projective objectives that are designed as three-belly systems having three bellies and two waists lying between the

bellies. There is a pair of lenses with mutually facing, aspheric lens surfaces in the region of the waist between a first lens group, following the object plane, of positive refractive power and a second lens group, follow-

5 ing thereupon, of negative refractive power. This arrangement of aspheric lens surfaces arranged adjacent to one another on various lenses is also denoted there as a "double asphere". By comparison with precursor systems, the use of at least one double asphere in the region of the first belly rendered it possible to correct input telecentricity and distortion with the aid

10 of modest means over a short distance, an increase in the image-side numerical aperture having been achieved at the same time.

[0015] The advantageous actions of aspheres result essentially because it is possible with the aid of aspheric lens surfaces to set a specific variation,

15 which cannot be achieved by spherical lens surfaces, in the radial refractive power profile by suitable deformation of the asphere. In order here to achieve an optimum degree of freedom for the optical design by the use of aspheres, aspheres with strong deformations are increasingly becoming required. However, this results in problems, since the fabrication of

20 aspheric lens surfaces with strong deformations comes up against technological limits both with regard to the processing of the aspheric lens surface and with regard to the testing of the aspheric lens surface.

[0016] It is an object of the invention to provide an optical imaging system

25 for a microlithography projection exposure system that includes a number of aspheric lens surfaces for influencing its imaging properties, the production and testing of the aspheric surfaces being simplified by comparison with the prior art.

30 [0017] The invention provides an optical imaging system having the feature of claim 1 in order to achieve this object. Advantageous developments are specified in the dependent claims. The wording of all the claims is incorporated in the description by reference.

[0018] An optical imaging system according to the invention for a micro-lithography projection exposure system is used to image an object field arranged in an object plane of the imaging system into an image field arranged in an image plane of the imaging system. The optical imaging system comprises:

a plurality of lenses that are arranged between the object plane and the image plane and in each case have a first lens surface and a second lens surface,

at least one of the lenses being a double aspheric lens where the first lens surface and the second lens surface is an aspheric surface.

[0019] The optical imaging system that is also denoted below as a "lithography objective" therefore has at least two aspheric surfaces that are provided at one and the same lens such that both the entrance surface of the lens, and the exit surface of the lens are aspherically curved Such a lens is also denoted below as a "biasphere".

[0020] The inventors have found that it is possible by using double aspheric lenses of this type to provide lenses that have the action of an asphere with very strong deformation, and that can nevertheless be designed so that they can be produced with good quality and an acceptable outlay by using conventional methods for finishing and for testing the surfaces. If appropriate, a strong radial profile of the refractive power of an asphere can be produced by aspherization of the two lens surfaces of a lens. The contribution of the individual aspherical lens surfaces to the refractive power profile, and the deformation, attendant thereon, of the individual surfaces can nevertheless be kept so small that the surfaces can be produced and tested with an acceptable outlay.

[0021] In some embodiments, the first lens surface and the second lens surface of the double aspheric lens are shaped to be symmetrical relative to one another. A strong aspheric action can be achieved in this way in conjunction with minimal deformation. Symmetrical double aspheric lenses

are also advantageous with regard to fabrication and testing, since sub-stantially the same production and testing process can be used for both lens surfaces.

[0022] The double aspheric lens can be a biconvex positive lens or a bi-concave negative lens. Also possible are embodiments where the double aspheric lens is a meniscus lens, that is to say a lens in which the first lens surface and the second lens surface have the same sense of curvature. Double aspheres can also be formed as a planarconvex lens or planarcon-cave lens with a substantially flat, yet aspherized first lens surface and an aspherically curved second lens surface as well as a plane-parallel plate with an aspheric component on both sides.

[0023] It has proved to be advantageous with regard to simplified fabrica-tion and testing when the first lens surface and the second lens surface of the double aspheric lens have substantially the same surface description with reference to curvature and aspheric constants. They can thus be sub-stantially of identical shape.

[0024] A simplified testing can be achieved by shaping a first aspheric lens surface and a second aspheric lens surface such that they can substan-tially be transformed into one another by means of an orthotomic projec-tion. With reference to a surface of prescribed surface shape, an orthoto-mic light bundle is a light bundle whose rays are in each case normals to the surface onto which the light bundle falls. If use is made when testing aspheres of test optics that are shaped such that the emerging light falls substantially perpendicular to the aspheric surface to be tested, such a test optics can be used unchanged for the purpose of testing aspheres of dif-ferent size as long as their aspheric surfaces can be transformed into one another by an orthotomic projection.

[0025] In general, first and second aspheric lens surfaces are advanta-geous when both surfaces are "similar" aspheres in the sense that they can

be tested with the same test optics, if appropriate given a different working distance or testing distance.

[0026] The advantages that are afforded thereby, namely that at least two aspheric lens surfaces inside an optical imaging system have an essentially identical surface description with reference to curvature and aspheric constants, and/or can substantially be transformed into one another by means of an orthotomic projection, and/or are substantially shaped such that they can be tested with the same test optics, can be utilized not only when using double aspheric lenses according to the invention. Rather, mutually similar or identical aspheres can also be arranged on various lenses of an imaging system, if appropriate at a large distance from one another and/or with at least one optical surface lying therebetween. The advantages are retained with regard to the ability to produce and test.

[0027] In one development of the invention, the double aspheric lens is arranged in a region of the imaging system close to a field and therefore acts as a field lens. A "region close to a field" in this sense is, in particular, a region that lies in the vicinity of a field plane of the imaging system and in which the marginal ray height of the optical imaging is smaller than or small by comparison with the principal ray height. In the region close to a field, the marginal ray height is typically less than 50%, 40%, 30%, 20% or 10% of the marginal ray height in the region of an aperture-limiting stop. An effective correction of distortion as well as a setting of the telecentricity in the closest field plane is possible with the aid of double aspheric lenses close to a field.

[0028] There are embodiments in which the imaging system is a relay objective or REMA objective for imaging an illumination field arranged in an intermediate field plane of an illumination system into an exit plane of the illumination system. It has proved to be advantageous here when the double aspheric lens is the last one of the imaging system, closest to the image plane. As a result, the central function of such objectives, specifically

the compensation of the telecentric error of the subsequent projection objective, is optimally fulfilled without the need to fabricate aspheric lenses with excessively strong deformation. The symmetrical shaping already mentioned has proved to be advantageous in order to achieve the desired aspheric action by comparison with conventional systems having a substantially lesser local curvature at the surface. Since the aspheres enable a large variation in the radial refractive power profile in conjunction with moderate deformation of the individual surfaces within a short installation space, biaspheres close to a field enable the generation and/or compensation of large telecentric errors.

[0029] Whereas in some embodiments the exit-side double asphere is, if appropriate, a symmetrical biconvex lens, other embodiments the double asphere closest to the exit plane is shaped as a meniscus lens, in particular with a concave side directed toward the object, that is to say with an image-side convex surface.

[0030] In accordance with one development, the imaging system is a projection objective for imaging a pattern of a mask arranged in an object plane of the projection objective into the image plane of the projection objective. The projection objective can be a rotationally symmetrical, purely refractive projection objective. Although systems with three or more bellies between the object plane and image plane are also possible, a preferred projection objective is designed as a two-belly system having an object-side belly, an image-side belly and a waist lying therebetween. Such a system has a first lens group, following the object plane, of negative refractive power, a second lens group, following thereupon, of positive refractive power, a third lens group, following thereupon, of negative refractive power, a fourth lens group, following thereupon, of positive refractive power, and a fifth lens group, following thereupon, of positive refractive power, a system aperture being arranged in the transition region between the fourth and fifth lens group. The double aspheric lens can be arranged in the vicinity of the object plane, in particular inside the first lens group. In one embodiment,

the double aspheric lens has negative refractive power, it being shaped as a biconcave meniscus lens, in particular. If a double aspheric lens is the lens of the imaging system that is closest to the object plane, a particularly

5   strong influence on telecentricity and the correction of distortion is possible in a small installation space.

[0031] The invention can also be used in catadioptric systems with or without an intermediate image, in particular in systems having a geometric

10   beam splitter or a physical, polarization-selective beam splitter. For example, a double aspheric lens close to a field can be present in the entrance region close to the object plane or in the vicinity of the intermediate image.

[0032] The invention can equally well be used for "air objectives" and for

15   "immersion objectives". An air objective in this sense is a projection objective in which during operation an interspace filled with air or another gas exists between the image-side exit surface and the image plane. By contrast, an immersion objective is distinguished by the fact that during operation the interspace between an exit side of the objective and the image

20   plane is filled with an immersion medium of high refractive index, for example an immersion liquid such as water, perfluoropolyether (PFPE) or the like. Image-side numerical apertures of $NA \geq 1$ are possible in this case.

[0033] The aim when shaping the aspheric lens surfaces with regard to fab-

25   rication and testing is as slight as possible deformations. The "deformation" of an aspheric lens surface is defined here as the extent of the deviation of a spherical lens surface (enclosing sphere), adapted in the best way to the aspheric surface, of the aspheric lens surface. The enclosing sphere is laid in this case such that it touches the aspheric lens surface at its apex and at

30   the outer edge. With regard to fabrication, it is customary to determine the extent of the deformation, that is to say the distance between the enclosing sphere and aspheric surface, in a radial direction of the enclosing sphere. From the point of view of optical design, the deformation is alternatively specified as distance in the axial direction. The last-named definition is

used in this application.

[0034] In the sense of this application, aspheres are, in particular, so-called "design aspheres" that are provided from the beginning in the optical design for the purpose of optimizing the system. Such design aspheres typically have maximum deformations of clearly more than 1 to 5 μm, and differ from so-called "correction aspheres", which are inserted subsequently, if appropriate, into optical imaging systems in order to correct aberrations. Aspheres are, in particular, all optical surfaces with a rotationally symmetrical deviation from the enclosing sphere where the deviation is more than 5 μm. Useful deviations are predominantly of the order of magnitude of 0.1 mm to 1 mm.

[0035] In the case of advantageous embodiments, aspheric surfaces are possible for which the maximum deformation is less than 500 μm, in particular less than 400 μm or less than 300 μm. This facilitates the fabrication and testing of the aspheres.

[0036] The invention also relates to a design method for producing an optical imaging system for a microlithography projection exposure system, the imaging system being provided for imaging an object field arranged in an object plane of the imaging system into an image field arranged in an image plane of the imaging system, and having a plurality of lenses that are arranged between the object plane and the image plane, and it being permitted to provide an aspheric effect of at least one aspheric optical surface in order to influence the imaging. In the method, a first aspheric lens surface and at least one second aspheric lens surface are calculated by means of appropriate algorithms in a calculation program such that a combination of the first and the second aspheric lens surfaces is formed in order to produce the aspheric effect, and that the first aspheric lens surface and the second aspheric lens surface are deformed similarly in such a way that they can be tested with the same test optics. The method can be integrated into existing computer programs by means of suitable programming.

[0037] Apart from proceeding from the claims, the existing and further features also proceed from the description and the drawings, it being respectively possible to implement the individual features on their own or severally in the form of subcombinations in one embodiment of the invention and in other fields, and to constitute advantageous designs that are patentable per se.

[0038]

Figure 1   shows a schematic of an embodiment of a projection exposure system for microlithography;

Figure 2   shows an embodiment of an inventive imaging system that is designed as a refractive two-belly projection objective;

Figure 3 and 4 show reference systems relating to the projection objective in accordance with figure 2;

Figure 5   shows a first embodiment of an inventive imaging system that is designed as a REMA objective for an illumination system of a projection exposure system;

Figure 6 and 7 show schematics relating to the dependence of the local curvature C on the relative aperture on aspheric lens surfaces of a symmetrical double aspheric lens;

Figure 8   shows a diagram relating to the pupil function of the REMA objective in accordance with figure 5;

Figure 9   shows a diagram that illustrates the dependence of the telecentric error on the image height of the REMA objective in accordance with figure 5, for various settings;

Figure 10   shows a diagram that illustrates the dependence of the uniformity error of the image height of the REMA objective in accordance with figure 5, for various settings;

Figure 11   shows a second embodiment of an inventive imaging system configured as a REMA objective;

Figure 12   shows a third embodiment of an inventive imaging system configured as a REMA objective;

Figure 13   shows a fourth embodiment of an inventive imaging system configured as a REMA objective;

Figure 14   shows a schematic of the effect of various shapings of aspheres on the shape of a wavefront passing through;

Figure 15   shows a lens section through the image-side end region of a catadioptric immersion projection objective; and

Figure 16   shows a variant of the projection objective shown in figure 15, with aspheric lens surfaces similar to one another.

[0039] In the following description of preferred embodiments, the term "optical axis" denotes a straight line through the centers of curvature of the spherical optical components or through the axes of symmetry of aspheric elements. Directions and distances are described as being on the image side or as toward the image when they are pointed in the direction of the image plane, and as on the object side or toward the object when they are directed toward the object with reference to the optical axis.

[0040] Figure 1 shows an exemplary embodiment of a projection exposure system 1 for microlithographic production of integrated semiconductor

components   and   other   finely   structured subassemblies at resolu-
tions of up to 0.1 µm or below. The projection exposure system 1 com-
prises an illumination system 2 for illuminating a photomask 5 (reticle) ar-
ranged in the exit plane or image plane 4 of the illumination system, as well

5   as a projection objective 6 that is provided for the purpose of imaging the
pattern of the photomask arranged in its object plane 4 into the image
plane 7 of the projection objective on a reducing scale. A semiconductor
wafer coated with a photosensitive layer is located in the image plane 7 as
an object to be exposed.

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[0041] Serving as a light source of the illumination system 2 is a laser 8, for
example an excimer laser, customary in the deep ultraviolet (DUV) region
and having an operating wavelength of 248 nm, 193 nm or 157 nm. The
light of the output light beam is largely linearly polarized. A subsequent op-

15   tical device 9 shapes the light of the light source and transmits it into a
subsequent light mixing device 10. In the example shown, the optical de-
vice 9 comprises a beam expander that is downstream of the laser 8 and
serves the purpose of reducing coherence and shaping the beam to a rec-
tangular beam cross section with an aspect ratio x/y of its side lengths of

20   more than one. A first diffractive optical raster element subsequent to the
beam expander is seated in the object plane of a subsequent zoom objec-
tive, in whose exit pupil a second optical raster element is provided. From
the latter, the light enters an encoupling optics that transmits the light into
the light mixing device. The light is mixed and homogenized inside the light

25   mixing device 10 by multiple internal reflection, and exits at the exit 11 of
the light mixing device in a largely homogenized fashion. Arranged directly
at the exit of the light mixing device is an intermediate field plane in which a
reticle masking system (REMA) 12, an adjustable field stop, is arranged.
The subsequent objective 13, which is also denoted as REMA objective,

30   has a number of lens groups, a pupil plane 14 and a deflecting mirror 15,
and images the intermediate field plane of the reticle masking system onto
the reticle or the photomask 5.

[0042] The design of the previously described illumination system can substantially correspond to the design described in EP 0 747 772, the disclosure content of which is incorporated in this description by reference.

[0043] The entrance plane 21 of the light mixing device 10, which coincides with the rear focal plane of the upstream encoupling optics is a field plane of the illumination system. The exit plane of the light mixing device, in the region of which the reticle masking system 12 is arranged, is likewise a field plane. In other embodiments with a similar basic design, the optical devices present up to the exit plane of the encoupling optics are shaped such that the illumination distribution within this field plane is sufficiently uniform. No separate light mixing device is provided in the case of these embodiments, and so the reticle masking system can be arranged directly in the region of the exit plane of the encoupling optics.

[0044] A typical design of an embodiment of an inventive, purely refractive reduction objective 200 is shown in figure 2. It serves the purpose of imaging a pattern, arranged in its object plane 202, of a reticle or the like into an image plane 203 on a reduced scale, for example, on the scale 4:1 (linear magnification β = 0.25). This is a rotationally symmetrical one-wayist system or two-belly system with five consecutive lens groups that are arranged along the optical axis 204 perpendicular to the object plane and image plane. The first lens group LG1 following the image plane 202 has negative refractive power (with a focal length of -546.86 mm). A second lens group LG2 following thereupon has positive refractive power (with a focal length of 205.97 mm). A third lens group LG3 following thereupon has negative refractive power (and a focal length of -55.62 mm). A fourth lens group, following thereupon, has positive refractive power (and a focal length of 216.53 mm). A fifth lens group LG5, following thereupon, has positive refractive power (and a focal length of 121.10 mm). This distribution of refractive power produces a two-belly system that has an object-side belly 206, an image-side belly 208 and a waist 207 that lies therebetween and in which a site of constriction X with a minimum beam diameter lies. The sys

tem aperture 205 lies in the region of relatively large beam diameters in a transition region from the fourth lens group to the fifth lens group.

[0045] The imaging possible with the aid of the projection objective can be characterized by the course of its principal rays and marginal rays. Denoted here as principal ray A is a ray that runs from an outer marginal point of the object field in a fashion parallel, or at an acute angle, to the optical axis, and cuts the optical axis 204 in the region of the system aperture 205. A marginal ray B leads from the middle of the object field, that is to say from an axial field point, to the edge of an aperture stop that is normally seated at the location of the system aperture 205 or in the immediate vicinity thereof. A ray C, that leads from an outer field point to the opposite edge of the aperture stop, is denoted here as a coma ray. The perpendicular distance of these rays from the optical axis yields the corresponding ray heights h_A, h_B and h_C.

[0046] A first lens region LB1 begins at the object plane 202 and ends in the plane in which the marginal ray B and the coma ray C intersect such that the condition $|h_B/h_C| < 1$ is fulfilled in the first lens region LB1. The principal ray height is large by comparison with the marginal ray height in this lens region LB1. The lens surfaces arranged here are denoted as "particularly close to a field". A second lens region LB2 extends from the object plane 202 as far into the region in which the principal ray height and the marginal ray height are approximately equal in terms of magnitude, it applying, in particular, that $|h_B/h_A| < 1.2$. In typical variants of inventive projection systems, the length of the second lens region LB2 is smaller than one third of the distance L between the object plane 202 and image plane 203. This object/image distance is also denoted as the design length of the projection objective.

[0047] The first lens group LG1 following the object plane 202 is substantially responsible for expanding the light bundles in the first belly 206. A negative lens 211 with a convex entrance side relative to the object plane

and a concave exit side on the image side is provided as first lens directly following the object plane 202. Both lens surfaces (surfaces 2 and 3 in Table 1) are aspheric surfaces, and so the negative lens 211 is also denoted here as a "double aspheric lens" or "biasphere".

[0048] There follows a double spherical meniscus lens 212 of weak refractive power and, downstream thereof, a positive meniscus 213 with an object-side aspheric concave surface. The aspheric surfaces, arranged particularly close to the field, of the double aspheric lens 211 contribute to the good correction of the distortion and of the astigmatism, and provide support for the correction with regard to telecentricity.

[0049] The second lens group LG2 comprises four positive lenses 214, 215, 216, 217. An entrance-side meniscus lens 214 with a virtually flat, object-side concave entrance surface and spherical exit surface is followed by a further virtually planarconvex positive lens with a spherical entrance surface and a virtually flat aspheric exit surface. Following thereupon are a double spherical positive meniscus 216, a thick positive meniscus lens 217 with a spherical entrance surface and an aspheric exit surface that is concave on the image side. This design, in which the curvatures of the lens surfaces on the object side and image side of a plane lying between the lenses 214, 215 run in opposite directions and with concave surfaces averted from one another, ensures small surface loadings for the meniscuses and the positive lenses and thus slight aberrations.

[0050] The third lens group LG3 comprises three negative lenses 218, 219, 220. A double spherical meniscus lens 218 with a concave surface on the image side is followed by a negative meniscus lens 219 which is concave on the object side and has an image-side asphere and a double spherical biconcave lens 220. The location X of narrowest constriction inside the waist 207 lies in the entrance region of the lens 219.

[0051] The fourth lens group LG4 starts with a positive meniscus lens 221,

concave relative to the object plane, with an aspheric entrance surface that is followed by a negative meniscus 222 with a virtually flat entrance surface and spherical exit surface concave on the image side. Seated behind a subsequent double spherical biconvex lens 223 is a positive meniscus 224, concave relative to the image plane, with a spherical entrance side and aspheric exit side. Striking inter alia are the large incident angles, occurring on the exit side of the meniscus 222, in the region of the divergent ray bundle, which contribute to the correction.

[0052] The fifth lens group LG5 starts with a double spherical negative meniscus 225 with an image-side concave side that projects into the region of the system aperture. Following this are six positive lenses 226, 227, 228, 229, 230, 231, of which the first lens 226 is biconvex, while the remaining are designed as positive meniscuses concave on the image side. The exit sides of the lenses 227 and 229 are aspheric, while the other lens surfaces are spherical. The system ends with a plane-parallel plate 232.

[0053] The double telecentric system has an object-side operating distance of approximately 32 mm and an image-side operating distance of 5 mm. The specification of the design is summarized in Table 1 in tabular form in a known way. Here, column 1 specifies the number of a surface distinguished as refractive or in some other way, column 2 specifies the radius r of the surface (in mm), column 3 specifies the distance d, denoted as thickness, of the surface from the subsequent surface (in mm) and column 4 specifies the material of the optical components. Column 5 specifies the refractive index of the lens material, and column 6 specifies the useful, free radii or half the free diameter of the lenses (in mm).

[0054] Eleven of the surfaces, particularly the surfaces 2, 3, 6, 11, 15, 19, 22, 29, 36, 38 and 40, are aspheric in the embodiment. Table 2 specifies the corresponding aspheric data, the aspheric surfaces being calculated using the following rule:

$$p(h)=[((1/r)h^2)/(1+SQRT(1-(1+K)(1/r)^2h^2))]+C1{*}h^4+C2{*}h^6+...$$

[0055] Here, the reciprocal (1/r) specifies the radius of the surface curvature, and h the distance of a surface point from the optical axis (that is to say the ray height). p(h) therefore provides the so-called sagitta, that is to say the distance of the surface point from the apex of the surface in the z-direction, that is to say in the direction of the optical axis. The constants K, C1, C2, ... are reproduced in Table 2.

[0056] The optical system reproducible with the aid of these data is designed for an operating wavelength of approximately 193 nm, at which the synthetic silica glass used for all lenses has a refractive index n = 1.5608. The image-side numerical aperture is NA = 0.95. The objective has a design length L (distance between the image plane and object plane) of 1101 mm. Given an image size of approximately 14 mm, a light conductance value (product of numerical aperture and image size) of approximately 13.3 mm is reached.

[0057] Particular features of this design are now explained in conjunction with figures 3 and 4, which show reference systems that have a virtually identical lens sequence except for the region of the objective entrance. The specifications of the embodiment in figure 3 is specified in Tables 3 and 4, those of the embodiment in accordance with figure 4 being specified in Tables 5 and 6.

[0058] All three systems have substantially the same, good correction state.

[0059] In the reference system in figure 3, the first lens, next to the object plane 202, is formed by a planarconcave negative lens 311 where the flat entrance surface is followed by a strongly deformed, aspheric exit surface (surface 3 in Table 3). This aspheric surface has a maximum deformation of approximately 1037 µm. The system can be effectively corrected, in par

ticular, even with regard to telecentricity and distortion, with the aid of this strong deformation. However, the deformation is so large as to present difficulties in producing and testing such an asphere.

[0060] In the reference system 400 in accordance with figure 4, two negative lenses 411, 411' are provided instead of one negative lens 311 in the region close to an object or close to a field. In both negative meniscuses, the entrance side respectively assigned to the object plane is aspherized, while the exit side that is concave relative to the image plane is spherically curved. Since the total deformation in the region near a field that is required for correction is distributed here over two aspheric surfaces (on different lenses), the deformations of the individual aspheric surfaces can be kept substantially smaller than in the example in accordance with figure 3, fabrication and testing thereby being facilitated. However, two additional surfaces that can cause light losses are introduced. In addition, stringent requirements are placed on the relative positioning of the aspheric surfaces lying closely next to one another.

[0061] The problems occurring with the reference systems can be avoided in the inventive embodiment in accordance with figure 2. In the negative lens 211, the total deformation is distributed over the two aspheric lens surfaces such that a biasphere is formed. The deformations of the individual lens surfaces lie in the range below 500 µm. Deformations in this range can be effectively mastered during production and testing, and so such a biasphere can be produced with high quality. The arrangement of the double aspheric lens, acting as field lens, in the direct vicinity of the object plane 202 permits an effective correction of field aberrations.

[0062] Alternatively, or in addition, one or more biaspheres can also be provided in other regions of the projection objective, for example in the region of the image-side exit.

[0063] Figures 5 to 13 are used to describe by way of example the use of

biaspheres in the field lens part of REMA objectives with the aid of which in the region of the adjustable stop formed by the REMA system can be imaged inside the illumination system onto the reticle to be exposed on a

5   suitable scale (typically between approximately 1:1 and approximately 1:4 to 1:5). The images are therefore enlarging as a rule, but can also be performed substantially without a change in field size, or even in a slightly reducing fashion.

10   [0064] Figure 5 shows an embodiment of such a REMA objective 500 that is designed for an operating wavelength of 193 nm and an approximately 1:1 imaging (β = 0.98). The specification is set forth in Tables 7 and 8. The objective has an object plane 502 in which the reticle masking system is arranged. There follows a condenser part 550 that is upstream of the aper-

15   ture stop 505 and designed as a partial objective. Beginning downstream of the aperture stop 505 is an intermediate part 560 that extends between the aperture stop and an imaginary plane 506 in which a deflecting mirror for example can be arranged. Beginning downstream thereof is a field lens part 570 that, in the vicinity of the image plane 503 in which a reticle to be

20   exposed is located during operation of the system, comprises a number of lenses arranged in the vicinity of the image field. The air spaces in the region of the object plane 502, in the region of the aperture stop 505, between the intermediate part 560 and the field lens part 570 as well as in the region of the reticle plane or image plane 503 are so generously dimen-

25   sioned that the parts to be arranged there and, in particular, the REMA system (reference numeral 12 in figure 1), correction elements in the stop plane, a deflecting mirror (reference numeral 15 in figure 1) and a reticle stage for moving the masks to be arranged in the image plane can be accommodated without a problem.

30

[0065] A principal function of the REMA objective 500 is to image a bright/dark edge, defined by the cutting of the REMA stop, sharply from the object plane 502 onto the reticle plane 503. A further core function of the REMA objective is to adapt the direction of the centroid ray of the emerging

rays, down to a few mrad (for example 3 mrad) to the directions of the prin-
cipal rays of the downstream projection objective. This is equivalent to the
requirement of reproducing a prescribed pupil function with the least devia-
tions in the exit plane (reticle plane 503).

[0066] The condenser part 550 comprises a positive meniscus lens 511,
concave on the object side, with a spherical entrance surface and exit-side
aspheric surface, and a further positive meniscus lens 512 with a spherical
entrance surface and exit-side aspheric surface. The intermediate part 560
following downstream of the aperture stop comprises a further positive me-
niscus lens 513 with a spherical entrance surface and exit-side aspheric
surface. The field lens part 570 has a positive meniscus lens 514, concave
on the image side, with an aspheric entrance surface and spherical exit
surface, a positive meniscus lens 515, concave on the image side, with a
spherical entrance surface and spherical exit surface, a diverging planar-
concave lens 516 with a flat entrance surface and aspheric exit surface. A
double aspheric lens 517 with an aspheric entrance surface and aspheric
exit surface is provided at the last, exit-side lens of the REMA objective.
Still following downstream thereof are two plane-parallel plates 518, 519
and the reticle 520. The biasphere 517 is of substantially symmetrical de-
sign with reference to a plane of symmetry lying perpendicular to the opti-
cal axis, such that the aspheric entrance surface and the aspheric exit sur-
face are formed in an essentially mirror-symmetric fashion relative to one
another. For the purposes of illustration, in this regard figure 6 shows
schematically the typical profile of the local curvature C of the entrance
side as a function of the relative aperture (Re. Ap.) for the case of a com-
parable embodiment. Figure 7 shows the corresponding illustration for the
exit side of the biasphere. A comparison of the figures shows the far-
reaching symmetry of the curvature profiles.

[0067] The system has numerous special features, some of which are de-
scribed in more detail below. The linear magnification is 1:0.98. All the
elements with a center thickness of less than 10 mm are made from CaF_2

(n = 1.501403 at 193 nm) in order to minimize compaction there. This relates to the filter plates 518, 519, the reticle 520 and the penultimate lens 516. This can be advantageous, because there is the suspicion that thin

5   lenses, in particular, suffer more severely under birefringence owing to compaction. Other lenses are made from synthetic silica glass (n = 1.560318). The concave asphere on the exit side of lens 515 is controlled such that its deviations from the curvatures of a sphere do not contain points of inflection. The aspheric surfaces of the double aspheric lens 517,

10   which are principally responsible for the telecentric profile are controlled such that their tangents always preserve the same sign. In order to simplify fabrication, the aspheres of the first four lenses 511 to 514 are respectively on the convex side. The sagging of the lens 513 is kept small in order to save material. The lens 513 close to the pupil is made from CaF_2 in order

15   to ensure radiation resistance for small settings. The pupil is optimized to a transverse deviation of less than 0.75 mm. It is thereby possible to introduce a stop in order to limit the settings in order, if appropriate, to minimize scattered light in the case of small settings. The overall length is 1418 mm.

20   [0068] Figure 8 shows that pupil function which is to be set in the field plane 503 (reticle plane). The telecentric angle [mrad] is illustrated to this end as a function of the image height r[mm]. Figure 9 shows the dependence of the telecentric error [mrad] on the image height y. It may be seen that the maximum telecentric error is < 0.2 mrad for an annular setting of <

25   0.3 mrad. It is to be seen from figure 10 that the maximum uniformity error plotted on the ordinate is < 0.05%, a field profile of up to 100.5% being set in order to maintain the transmission or the layer influences. The planar-concave negative lens 516 serves as manipulator for compensating uniformity errors with a linear field profile.

30

[0069] The biasphere 517 enables a large variation in the radial refractive power profile in the case of moderate deformation of the individual surfaces inside a very short installation space that is determined by the axial thickness of the biasphere. If such a biasphere is positioned in the immediate

vicinity of the image field, it is possible to correct large telecentric errors, or to set any desired pupil functions within wide limits. Despite the strong aspheric action, the biasphere is relatively unproblematic with regard to the fabrication of its surfaces and to the testing of the surfaces, since only relatively slight surface deformations occur. In addition, testing can be carried out using one and the same test optics owing to the symmetry of the two aspheric surfaces, and this substantially eases the outlay on testing.

[0070] Figure 11 shows another variant of an inventive lithography objective 600 that is designed as REMA objective for 248 nm. The exit-side biasphere 690 is shaped here as a positive meniscus lens with a concave surface on the object side in conjunction with basically the same division into a condenser part 650, an intermediate part 660 and a field lens part 670.

[0071] The system has an enlarging linear magnification β = -4.73. The object field diameter is 27 mm. The object-side numerical aperture is 0.127. The design length is 1200 mm. An edge sharpness of 0.1-99.9% - exactly 0.253 mm is achieved. The pupil function (desired value and actual value) is specified in Table 9, while the specification comes from Tables 10 and 11.

[0072] Another variant of an inventive lithography objective 700, which is designed as a REMA objective for 248 nm, is shown in figure 12. Here, in conjunction with basically the same division into a condenser part 750, an intermediate part 760 and a field lens part 770, the exit-side biasphere 790 is shaped as a positive meniscus lens with a concave surface on the object side and a relatively strong curvature.

[0073] The system has an enlarging linear magnification β = -4.73. The object field diameter is 27 mm. The object-side numerical aperture is 0.127. The design length is 1200 mm. An edge sharpness of 0.1-99.9% - exactly 0.251 mm is achieved. The pupil function (desired value and actual value)

is specified in Table 12, while the specification comes from Tables 13 and 14.

5   [0074] Another variant of an inventive lithography objective 800, which is designed as a REMA objective for 248 nm, is shown in figure 13. Here, in conjunction with basically the same division into a condenser part 850, an intermediate part 860 and a field lens part 870, the exit-side biasphere 890 is shaped as a positive meniscus lens with a concave surface on the object 10   side.

[0075] The system has an enlarging linear magnification β = -4.73. The object field diameter is 27 mm. The object-side numerical aperture is 0.127. The design length is 1200 mm. An edge sharpness of 0.1-99.9% - exactly 15   0.244 mm is achieved. The pupil function (desired value and actual value) is specified in Table 15, while the specification comes from Tables 16 and 17.

[0076] The examples so far show possibilities for using a plurality of 20   aspheric surfaces in the case of lithography objectives without coming up against technological limits in fabrication and testing because of strong deformations of the aspheres. Further measures for avoiding such problems are proposed in conjunction with figures 14 to 16. As mentioned at the beginning, in optical design a customary approach to reducing aspheric de- 25   formation is to introduce further aspheres at a point with strongly deformed aspheres in order to distribute the strong deformation over a number of more weakly deformed aspheres. The inventors have now found out that great technological advantages can be yielded in the case of this procedure when, instead of one strongly deformed aspheric surface, use is made 30   of two or more identically or at least similarly aspherized surfaces with a correspondingly weaker deformation. It is true that a division into two or more identical or similar aspheric surfaces slightly increases the outlay on fabrication, since a number of surfaces need to processed. However, the surface processing of all the identical aspheres can substantially proceed

in accordance with the same program. In particular, identical and similar aspheric surfaces can be tested with the same test optics such that a substantial outlay on testing can be saved.

5

[0077] This basic idea will be explained in more detail with the aid of figure 14. Figure 14(a) shows a plane-parallel plate 900 that is transirradiated by a plane wave. It is to be seen with the aid of the schematically depicted wavefront 901 that the plane wave upstream of the plane-parallel plate and

10   downstream of the plane-parallel plate has no aberrations and that therefore a plane wave remains. If, according to figure 14(b), one side of the plane-parallel plate is now deformed with a deformation d (x, y), the continous wavefront acquires a wave aberration such that a slightly deformed wave 901' results. The wave aberration can be described substantially in

15   the zero order immediately downstream of the "thin" plate by the product (n-1) * d(x, y), n being the refractive index of the plate. If, in accordance with figure 14(c) the asphericity is doubled starting from figure 14(b), there is also a doubling of the wave deformation.

20   [0078] However, if, in turn, starting from the situation in figure 14(b), an identical aspheric surface is once again also applied to the exit side of the plane-parallel plate, it is possible as a result for the wave aberration likewise to rise to 2 * (n-1) * d(x, y) (figure 14(d)). The effects of the entrance-side aspheric surface and the exit-side aspheric surface of the double

25   aspheric lens 911 formed thereby are added together so that the effect seems to gradually form an asphere with a deformation of 2 * d(x, y). It is therefore conceivable in principle to distribute an asphere with the deformation 2*d(x,y) over two aspheres each having identical deformations of d(x,y).

30

[0079] It is likewise possible in an optical imaging system, for example a projection objective for microlithography, to distribute an asphere with a large deformation over two aspheres with a lesser, but the same or similar deformation, or to relieve an asphere with deformation that is threatening to

become greater than a permissible limit value by a second, identical or

similar asphere. This can be carried out such that the entire deformation

5   corresponds substantially to the sum of the two deformations so that it is
possible to reach apparently larger, effective deformations.

[0080] If the surface curvatures of the mutually supplementary aspheric
surfaces are in agreement completely or at least predominantly, an identi-

10   cal test optics can be used for testing the additional aspheric surface. As a
result, no extra outlay is generated in the case of testing, it merely being
necessary to increase the number of the surfaces to be aspherized.

[0081] Starting from this basic principle, it will be necessary in a real design

15   to support the result of the method by subsequent optimization in order to
take account of a finite spacing between the two resulting aspheres.

[0082] It is, in addition, not mandatory for the mutually corresponding, iden-
tical or similar aspheric surfaces to be directly adjacent. It is also possible

20   for at least one optical surface, for example a spherical lens surface to be
situated between the mutually corresponding aspheric surfaces.

[0083] In a further development of the method, it is not necessary in princi-
ple for the mutually corresponding aspheric surfaces to be exactly identical.

25   It has emerged that it is also possible for the mutually supplementary or
corresponding aspheric surfaces to be shaped "similarly" in such a way
that they can be tested with the same test optics (given a different working
distance or testing distance). The substantial technological advantages
further ensue for testing in this case, as well.

30

[0084] It is provided in one variant of the method to produce a desired
aspheric action in which provision is made of at least two aspheric surfaces
that substantially emerge from one another or are transformed into one
another by means of an orthotomic projection. This means that the surface

normals to the aspheric surfaces that are similar in this sense form a "substantially orthotomic system". It is possible in this way even to test aspheres having different absolute dimensions with the aid of an identical

5   test optics, since it is possible in the case of all the aspheric surfaces belonging to an orthotomic system of the testing radiation provided by the test optics to impinge perpendicularly on these aspheric surfaces, thus facilitating testing.

10   [0085] Two or more aspheric surfaces to be compared need not form a perfect orthotomic system. It suffices when they form a "substantially orthotomic system" in the sense explained below: assuming that two aspheric surfaces to be compared are firstly arranged concentrically about a point with reference to the apex radius, a surface normal to the first surface then en-

15   closes an angle α at the respective intersection point with the surface normal to the second surface. It holds for an exactly orthotomic system that α ≡ 0 for all possible surface normals. It holds for a "substantially orthotomic system" in the sense of the application that

20   $$\sin(\alpha) \leq \frac{N}{(D/\lambda}$$

D being the optically free diameter of the aspheric surface, and λ the wavelength (for example 633 nm) used for testing. The apex spacing of the two surfaces now need no longer be given by the difference between the apex

25   radii, but is to be selected so as to minimize the maximum angle α that occurs. In the sense of the application, "substantially orthotomic systems" are involved, in particular, whenever it holds that N = 50, in particular N = 10 or N = 2. This means that the residual compensation of 50 or 10 or 2 interference fringes/diameters then occurs in an interferogram in the case of inter-

30   ferometric measurement.

[0100] Figure 15 shows an image-side end region of a catadioptric immersion projection objective 1000, designed for 193 nm, as an example of the

advantages of this design method. In a region close to the stop between

the   1005 and image plane 1003 a relatively strongly deformed aspheric
5   surface (surface 53) is positioned on the exit side of an approximately
planarconvex positive meniscus (maximum deformation approximately
400 μm). In the corresponding system in figure 16, the strongly deformed
aspheric surface was relieved by positioning on the exit surface, likewise
concave relative to the image plane, of the positive meniscus lens following
10   thereupon, a further aspheric surface (surface 55) that has substantially the
same surface description as that of the aspheric surface upstream thereof.
It was possible to halve the maximum deformation from approximately
400 μm to circa 200 μm by means of this measure, thus simplifying fabrica-
tion and testing. Moreover, it was even possible to substantially improve
15   the system performance from 12.0 mλ to 10.6 mλ. It is assumed that the
improvement to the system performance results in part from the fact that
higher-order deformations at the aspheric surfaces can be reproduced
when asphericity is distributed over more than one surface. The specifica-
tion of the systems is quoted in Tables 18 and 19 (re figure 10) and 20 and
20   21 (re figure 11).

Table 1

| r217v | | | | REFRACTIVE INDEX | 1/2 FREE |
SURFACE	RADII	THICKNESSES	LENSES	193.368 nm	DIAMETER
0	0.000000000	32.320000000	LUFTV193	1.00030168	56.080
1	0.000000000	0.000000000	LUFTV193	1.00030168	63.974
2	-1459.164104982AS	10.883642136	SIO2V	1.56078570	63.974
3	180.619581350AS	39.156911315	N2VP950	1.00029966	67.044
4	-107.911220584	84.781901584	SIO2V	1.56078570	68.729
5	-213.989607599	1.000000000	N2VP950	1.00029966	111.823
6	-412.845153739AS	45.792045149	SIO2V	1.56078570	120.332
7	-190.379523326	1.000000000	N2VP950	1.00029966	126.132
8	-4614.877843160	27.708693812	SIO2V	1.56078570	134.795
9	-457.274001084	1.000000000	N2VP950	1.00029966	135.949
10	420.000000000	30.000000000	SIO2V	1.56078570	137.193
11	35602.890285272AS	1.000000000	N2VP950	1.00029966	136.246
12	270.000000000	26.475451634	SIO2V	1.56078570	131.917
13	502.754294891	1.000000000	N2VP950	1.00029966	129.430
14	173.244893529	85.000000000	SIO2V	1.56078570	120.248
15	214.130898591AS	20.540800473	N2VP950	1.00029966	92.443
16	1272.514093441	39.820596617	SIO2V	1.56078570	90.281
17	110.781466896	74.295506424	N2VP950	1.00029966	68.947
18	-104.989672476	9.000000000	SIO2V	1.56078570	65.198
19	730.287776054AS	22.486936747	N2VP950	1.00029966	71.895
20	-307.597097235	9.262679110	SIO2V	1.56078570	75.360
21	451.935383561	17.226875006	N2VP950	1.00029966	83.667
22	-1494.299186899AS	38.937578772	SIO2V	1.56078570	87.442
23	-148.722559000	1.035639602	N2VP950	1.00029966	92.689
24	-3752.461411339	9.000000000	SIO2V	1.56078570	103.329
25	258.882844388	20.496820411	N2VP950	1.00029966	111.025
26	784.281838265	42.249678112	SIO2V	1.56078570	115.317
27	-299.834096576	1.000000000	N2VP950	1.00029966	119.214
28	252.743271757	38.035650313	SIO2V	1.56078570	152.454
29	462.923229099AS	46.891093164	N2VP950	1.00029966	151.679
30	0.000000000	-33.756526966	N2VP950	1.00029966	154.358
31	330.495802864	9.500000000	SIO2V	1.56078570	155.347
32	231.289261882	40.469468987	N2VP950	1.00029966	153.254
33	571.711143658	76.794483240	SIO2V	1.56078570	155.511
34	-290.609715959	1.000000000	N2VP950	1.00029966	157.318
35	237.617551020	57.120134799	SIO2V	1.56078570	153.853
36	1696.873913301AS	1.000000000	N2VP950	1.00029966	151.130
37	157.356137136	46.718690084	SIO2V	1.56078570	127.954
38	293.488395013AS	1.000000000	N2VP950	1.00029966	121.868
39	151.671762316	59.722817409	SIO2V	1.56078570	107.894
40	208.655839861AS	4.385810273	N2VP950	1.00029966	80.177
41	204.831099129	21.287882831	SIO2V	1.56078570	77.985
42	804.557271249	6.470098061	N2VP950	1.00029966	70.895
43	475.191683660	12.337210713	SIO2V	1.56078570	57.127
44	1142.238156752	5.049134278	N2VP950	1.00029966	48.974
45	0.000000000	9.468750000	SIO2V	1.56078570	36.676
46	0.000000000	5.000014319	LUFTV193	1.00030168	29.397
47	0.000000000	-0.000014316		1.00000000	14.020

TABLE 2

ASPHERIC CONSTANTS

SURFACE NO.   2

```
K       0.0000
C1      1.09119463e-007
C2     -5.30689084e-012
C3     -1.09315970e-016
C4      4.82752139e-020
C5     -2.47155650e-023
C6      1.58501935e-027
C7      0.00000000e+000
C8      0.00000000e+000
C9      0.00000000e+000
```

SURFACE NO.   3

```
K       0.0000
C1     -1.56384505e-007
C2      1.06996314e-011
C3     -1.05376927e-015
C4      1.85697980e-019
C5     -3.19176766e-023
C6      2.00274942e-027
C7      0.00000000e+000
C8      0.00000000e+000
C9      0.00000000e+000
```

SURFACE NO.   6

```
K       0.0000
C1      3.83956125e-009
C2      3.47868288e-013
C3     -1.28803865e-017
C4      1.18910850e-021
C5     -4.25647183e-026
C6      5.77188832e-031
C7      0.00000000e+000
C8      0.00000000e+000
C9      0.00000000e+000
```

SURFACE NO.   11

```
K       0.0000
C1      4.81120275e-009
C2      4.13520576e-014
C3     -5.36254054e-018
C4      3.56325685e-022
C5     -9.96093521e-027
C6      1.64692958e-031
C7      0.00000000e+000
C8      0.00000000e+000
C9      0.00000000e+000
```

SURFACE NO.   15

```
K       0.0000
C1     -1.61331019e-008
C2      3.52919257e-014
C3      3.06661268e-017
C4     -7.22002268e-021
C5      4.16057249e-025
C6     -2.31207963e-029
C7      0.00000000e+000
C8      0.00000000e+000
C9      0.00000000e+000
```

SURFACE NO.   19

```
K       0.0000
C1      1.27878859e-008
C2     -4.13979560e-012
C3     -4.07208879e-016
C4      5.26377145e-020
C5     -8.68076114e-025
C6     -6.17849743e-029
C7      0.00000000e+000
C8      0.00000000e+000
C9      0.00000000e+000
```

SURFACE NO.   22

```
K       0.0000
C1     -3.87264754e-008
C2      1.81612882e-012
C3     -1.09323759e-016
C4      2.55204344e-021
C5     -1.38859668e-025
C6      4.37920480e-030
C7      0.00000000e+000
C8      0.00000000e+000
C9      0.00000000e+000
```

SURFACE NO.   29

```
K       0.0000
C1      1.55648594e-009
C2      7.87201037e-014
C3     -7.46227893e-019
C4     -8.47715974e-023
C5      3.94573522e-027
C6     -5.27152158e-032
C7      0.00000000e+000
C8      0.00000000e+000
C9      0.00000000e+000
```

SURFACE NO.   36

```
K       0.0000
C1      1.38463693e-009
C2      9.34105890e-014
C3     -3.31978125e-018
C4      1.98461745e-022
C5     -5.31913432e-027
C6      7.36614617e-032
C7      0.00000000e+000
C8      0.00000000e+000
C9      0.00000000e+000
```

SURFACE NO.   38

```
K       0.0000
C1      1.23494614e-009
C2      4.07836082e-013
C3      5.52319264e-018
C4     -1.06214092e-021
C5      5.56801394e-026
C6     -1.09523279e-030
C7      0.00000000e+000
C8      0.00000000e+000
C9      0.00000000e+000
```

SURFACE NO. 40

K	0.0000
C1	1.76315794e-008
C2	3.90180649e-012
C3	1.77550556e-017
C4	-3.14301026e-021
C5	4.39156108e-025
C6	8.08125064e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

TABLE 3

r218v

REFRACTIVE INDEX SURFACE LENSES	1/2 FREE RADII 193.368 nm	THICKNESSES DIAMETERS
0	0.000000000	32.000000000
LUFTV193	1.00030168	56.080
1	0.000000000	0.000000000
LUFTV193	1.00030168	63.909
2	0.000000000	17.844950703
SIO2V	1.56078570	63.909
3	141.364869321AS	42.976532865
N2VP950	1.00029966	68.570
4	-106.379969384	78.027724995
SIO2V	1.56078570	70.336
5	-166.687860454	1.000000000
N2VP950	1.00029966	108.096
6	-453.543565041AS	26.035967427
SIO2V	1.56078570	118.587
7	-232.687652830	1.000000000
N2VP950	1.00029966	122.253
8	-4175.612871634	34.571195540
SIO2V	1.56078570	132.347
9	-339.014596070	1.000000000
N2VP950	1.00029966	134.146
10	500.000000000	34.007738554
SIO2V	1.56078570	137.817
11	-1979.358317517AS	1.000000000
N2VP950	1.00029966	137.328
12	275.000000000	38.615595029
SIO2V	1.56078570	131.717
13	713.420881508	1.000000000
N2VP950	1.00029966	127.146
14	219.840025272	85.000000000
SIO2V	1.56078570	118.935
15	321.375540921AS	4.922289739
N2VP950	1.00029966	92.215
16	408.796272617	25.823140797
SIO2V	1.56078570	89.829
17	101.545676471	72.090709976
N2VP950	1.00029966	70.185
18	-113.185080136	9.000000000
SIO2V	1.56078570	65.216
19	-6276.526315852AS	30.855400278
N2VP950	1.00029966	68.772
20	-137.418484927	17.333137381
SIO2V	1.56078570	70.621
21	413.789552546	20.404389259
N2VP950	1.00029966	84.304
22	-625.367774639AS	35.350033804
SIO2V	1.56078570	87.244
23	-140.888106901	1.000000000
N2VP950	1.00029966	91.874
24	2331.984028426	9.000000000
SIO2V	1.56078570	105.044
25	250.875405170	22.125324131
N2VP950	1.00029966	111.593
26	835.343130512	39.746104742
SIO2V	1.56078570	115.758
27	-326.784324219	1.000000000
N2VP950	1.00029966	119.638
28	255.433855640	46.317736953
SIO2V	1.56078570	153.611
29	490.028436327AS	42.760537386
N2VP950	1.00029966	152.582
30	0.000000000	-32.760537386
N2VP950	1.00029966	154.980
31	341.273585728	9.000000000
SIO2V	1.56078570	156.026
32	236.023249432	38.136711957
N2VP950	1.00029966	154.319
33	538.352989022	76.926527135
SIO2V	1.56078570	156.695
34	-303.854952853	1.000000000
N2VP950	1.00029966	158.497
35	242.471332890	55.345758805
SIO2V	1.56078570	156.649
36	1273.475455674AS	1.000000000
N2VP950	1.00029966	154.009
37	165.078804777	51.848716746
SIO2V	1.56078570	133.227
38	360.689088970AS	2.381005965
N2VP950	1.00029966	127.273
39	155.800125543	60.708631213
SIO2V	1.56078570	109.767
40	257.289833789AS	3.059278416
N2VP950	1.00029966	83.432
41	214.574391728	23.013966672
SIO2V	1.56078570	79.983
42	581.722478991	7.376730203
N2VP950	1.00029966	70.287
43	432.957343908	11.524326583
SIO2V	1.56078570	56.460
44	953.963555708	5.255374130
N2VP950	1.00029966	48.919
45	0.000000000	9.375000000
SIO2V	1.56078570	36.611
46	0.000000000	5.000014179
LUFTV193	1.00030168	29.403
47	0.000000000	-0.000014174
1.00000000	14.020	

TABLE 4

ASPHERIC CONSTANTS

SURFACE NO.   3

K	0.0000
C1	-2.86481339e-007
C2	1.33428721e-011
C3	-1.15140908e-015
C4	9.48184306e-020
C5	-5.08944755e-024
C6	1.72476575e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   6

K	0.0000
C1	-1.00040949e-008
C2	1.91234847e-014
C3	-3.08640325e-018
C4	2.26769898e-022
C5	-1.40237554e-027
C6	3.92572161e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   11

K	0.0000
C1	-1.62545449e-009
C2	-8.02017004e-014
C3	9.07741798e-019
C4	6.22361354e-023
C5	7.91274435e-029
C6	-2.44533345e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   15

K	0.0000
C1	-5.34383332e-008
C2	2.24730624e-012
C3	2.71223685e-018
C4	-5.23845943e-021
C5	1.96396121e-025
C6	-1.58673005e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   19

K	0.0000
C1	1.79672442e-009
C2	-6.77223099e-012
C3	-3.96951402e-016
C4	2.97275706e-020
C5	1.64172060e-024
C6	-2.76013991e-028
C7	0.00000000e+000
C8	0.00000000e+000

C9   0.00000000e+000

SURFACE NO.   22

K	0.0000
C1	-3.46618935e-008
C2	1.24390269e-012
C3	-4.83656616e-017
C4	1.75302648e-022
C5	1.21150441e-025
C6	-1.12186612e-029
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   29

K	0.0000
C1	2.91242380e-009
C2	5.36672462e-014
C3	-3.84138467e-019
C4	-5.83775573e-023
C5	3.05838142e-027
C6	-4.39732968e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   36

K	0.0000
C1	1.34059170e-009
C2	1.06725317e-013
C3	-3.54947088e-018
C4	1.30852468e-022
C5	-2.68379318e-027
C6	3.47219208e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   38

K	0.0000
C1	2.63154343e-009
C2	2.84724714e-013
C3	1.03599926e-018
C4	-5.71879023e-022
C5	3.15244493e-026
C6	-4.20712791e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   40

K	0.0000
C1	9.80415755e-009
C2	4.75026576e-012
C3	-1.99060433e-016
C4	9.51377978e-021
C5	-4.27716194e-025
C6	-5.70277764e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

TABLE 5

r221v

SURFACE	RADII	THICKNESSES	LENSES	REFRACTIVE INDEX 193.368 nm	1/2 FREE DIAMETER
0	0.000000000	32.320000000	LUFTV193	1.00030168	56.080
1	0.000000000	0.000000000	LUFTV193	1.00030168	63.987
2	-1414.283119543AS	8.000000000	SIO2V	1.56078570	64.113
3	424.792851760	5.648215816	N2VP950	1.00029966	65.856
4	1299.539331232AS	8.000000000	SIO2V	1.56078570	67.145
5	235.797454960	42.846403790	N2VP950	1.00029966	69.121
6	-102.370191138	69.189096195	SIO2V	1.56078570	70.860
7	-172.393415521	1.000000000	N2VP950	1.00029966	107.074
8	-311.506629059AS	37.876409079	SIO2V	1.56078570	116.081
9	-198.729331749	1.000000000	N2VP950	1.00029966	122.907
10	10618.353983725	37.816832272	SIO2V	1.56078570	134.690
11	-345.414077618	1.000000000	N2VP950	1.00029966	136.145
12	400.000000000	25.074567519	SIO2V	1.56078570	137.066
13	1543.425862196AS	1.000000000	N2VP950	1.00029966	136.002
14	250.000000000	44.417771731	SIO2V	1.56078570	132.858
15	424.538863322	1.000000000	N2VP950	1.00029966	125.810
16	174.877745836	70.000000000	SIO2V	1.56078570	118.444
17	243.447507091AS	14.188161571	N2VP950	1.00029966	98.000
18	484.930164939	48.000000000	SIO2V	1.56078570	95.965
19	111.938442661	77.053811810	N2VP950	1.00029966	71.061
20	-109.460895056	9.000000000	SIO2V	1.56078570	65.591
21	438.039183085AS	23.422549148	N2VP950	1.00029966	71.158
22	-202.054583818	9.000000000	SIO2V	1.56078570	72.631
23	465.572943863	16.082181763	N2VP950	1.00029966	82.930
24	-1172.049223927AS	36.326480405	SIO2V	1.56078570	86.214
25	-145.267929878	1.000000000	N2VP950	1.00029966	90.911
26	1353.417341936	9.000000000	SIO2V	1.56078570	105.237
27	254.308618512	21.441664729	N2VP950	1.00029966	111.540
28	808.549194446	40.139409419	SIO2V	1.56078570	115.722
29	-324.795643495	1.000000000	N2VP950	1.00029966	119.584
30	259.623325413	30.156883912	SIO2V	1.56078570	152.402
31	442.106202542AS	49.702134449	N2VP950	1.00029966	152.056
32	0.000000000	-35.918141056	N2VP950	1.00029966	155.705
33	321.189339694	13.200000000	SIO2V	1.56078570	156.875
34	235.938498925	38.959238636	N2VP950	1.00029966	154.952
35	548.092450535	78.619078346	SIO2V	1.56078570	157.303
36	-295.129602720	1.000000000	N2VP950	1.00029966	159.105
37	257.343015350	56.517809884	SIO2V	1.56078570	155.780
38	3502.742343640AS	1.000000000	N2VP950	1.00029966	153.286
39	153.633385258	50.277016535	SIO2V	1.56078570	128.279
40	298.509028204AS	1.000000000	N2VP950	1.00029966	122.045
41	149.675345185	60.980134477	SIO2V	1.56078570	107.243
42	190.178192400AS	5.453949973	N2VP950	1.00029966	77.382
43	197.572510486	20.628074249	SIO2V	1.56078570	75.169
44	718.043747110	5.783836616	N2VP950	1.00029966	68.036
45	479.704970402	11.372838185	SIO2V	1.56078570	56.262
46	1276.727595948	4.938062857	N2VP950	1.00029966	48.931
47	0.000000000	9.468750000	SIO2V	1.56078570	36.649
48	0.000000000	5.000014315	LUFTV193	1.00030168	29.372
49	0.000000000	-0.000014316		1.00000000	14.020

TABLE 6

ASPHERIC CONSTANTS

SURFACE NO.   2

K	0.0000
C1	2.08525794e-007
C2	-3.19987515e-011
C3	3.56280613e-015
C4	-3.77486884e-019
C5	2.10578968e-023
C6	-2.70937745e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   4

K	0.0000
C1	3.64477027e-008
C2	2.00816645e-011
C3	-2.98745270e-015
C4	2.91202348e-019
C5	-1.79522903e-023
C6	3.55575104e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   8

K	0.0000
C1	8.55962248e-009
C2	2.04733903e-013
C3	-6.43943314e-018
C4	5.73836441e-022
C5	-1.59385846e-026
C6	4.68346251e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   13

K	0.0000
C1	7.03699560e-009
C2	-1.52661867e-014
C3	-3.99418159e-018
C4	1.88604871e-022
C5	-4.98713537e-027
C6	1.16946921e-031
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   17

K	0.0000
C1	-9.76738019e-009
C2	1.42039979e-013
C3	2.09426135e-017
C4	-3.11005072e-021
C5	1.30236376e-025
C6	-9.13097296e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   21

K	0.0000
C1	1.14826642e-008
C2	-5.23285076e-012
C3	-3.60906300e-016
C4	4.17780521e-020
C5	4.11241516e-025
C6	-1.26961570e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   24

K	0.0000
C1	-3.11670458e-008
C2	1.40028813e-012
C3	-1.04629804e-016
C4	9.68145933e-022
C5	-8.29015519e-026
C6	-2.79089191e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   31

K	0.0000
C1	2.31274915e-009
C2	5.27830899e-014
C3	-2.07768704e-018
C4	-6.60919096e-023
C5	4.30024872e-027
C6	-5.82559285e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   38

K	0.0000
C1	1.22133020e-009
C2	9.82170002e-014
C3	-4.08875155e-018
C4	2.25637760e-022
C5	-5.76550179e-027
C6	7.24587177e-032
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.   40

K	0.0000
C1	2.01766742e-009
C2	3.58703800e-013
C3	1.38458390e-017
C4	-1.65456142e-021
C5	8.49511243e-026
C6	-1.87184616e-030
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

SURFACE NO.42

K	0.0000
C1	2.38088222e-008
C2	4.23623902e-012
C3	3.32178613e-017
C4	9.51247573e-021

C5	-1.75917666e-024
C6	2.13969194e-028
C7	0.00000000e+000
C8	0.00000000e+000
C9	0.00000000e+000

Table 7

Surface No.	Type	Radius [mm]	Center thickness [mm]	Material	Half dia-meter [mm]
	Object plane		79.2500		
1	Sphere	-99.4350	48.0000	'SIO2HL'	69.6
2	Asphere A(1)	-101.0810	156.6400		86.1
3	Sphere	-723.0640	70.0000	'SIO2HL'	120.7
4	Asphere A(2)	-183.9000	340.9100		126.9
	Stop		124.2000		73.5
5	Sphere	-180.6640	40.0000	'CAF2HL'	93.6
6	Asphere A(3)	-141.0650	107.0000		102.1
	Mirror	∞	138.7300		150.2
7	Asphere A(4)	172.4900	50.0000	'SIO2HL'	136.0
8	Sphere	596.7120	47.4580		133.5
9	Sphere	170.4950	56.0000	'SIO2HL'	117.3
10	Asphere A(5)	194.7400	30.7260		107.5
11	Sphere	infinity	7.2500	'CAF2HL'	93.4
12	Sphere	107.4480	30.7500		75.8
13	Asphere A(6)	413.1300	24.6400	'SIO2HL'	74.8
14	Asphere A(7)	-199.5060	1.2500		72.9
15	Sphere	∞	3.0500	'CAF2HL'	70.8
16	Sphere	∞	1.2500		70.3
17	Sphere	∞	3.0500	'CAF2HL'	70.0
18	Sphere	∞	51.4480		69.6
19	Sphere	∞	6.3000	'SIO2HL'	57.3
20	Sphere	∞	0.0000		56.8
	Image plane		0.0000		56.8

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Table 8

Asphere	Curvature	K	A	B	C	D	E
A(1)	-0.00989306	-1.016679	-6.011E-08	-2.104E-12	-8.452E-17	-9.101E-21	0.000E+00
A(2)	-0.00543774	0.172377	1.415E-08	5.799E-13	-5.406E-18	8.810E-22	0.000E+00
A(3)	-0.00708893	-0.740223	-1.794E-08	1.226E-13	-3.779E-17	1.585E-21	0.000E+00
A(4)	0.005799744	-0.487512	-1.532E-08	8.915E-14	-3.181E-19	-1.307E-22	0.000E+00
A(5)	0.00513505	-1.224675	-1.442E-07	7.613E-13	1.473E-16	-3.805E-21	0.000E+00
A(6)	0.002242055	-5.404462	-1.062E-07	8.090E-12	-3.350E-16	7.063E-19	-1.193E-22
A(7)	-0.00501238	1.430927	1.452E-07	1.114E-11	1.352E-15	5.307E-19	-9.312E-23

Pupil function:

Image field height [mm]	Actual value [mrad]	Actual-desired [mrad]
63,6	5,34	0,09
57,3	1,59	-0,10
51,0	-0,90	0,06
44,6	-2,65	0,10
38,3	-3,76	-0,01
31,9	-4,21	-0,10
25,5	-4,00	-0,08
19,1	-3,29	0,01
12,8	-2,28	0,09
6,4	-1,15	0,08

Table 9

Pupil function:

Image field height [mm]	Actual value [mrad]	Actual-desired [mrad]
63,6	5,34	0,09
57,3	1,59	-0,10
51,0	-0,92	0,04
44,6	-2,64	0,10
38,3	-3,74	0,01
31,9	-4,19	-0,09
25,5	-4,00	-0,08
19,1	-3,30	0,01
12,8	-2,28	0,09
6,4	-1,15	0,09

Table 12

Pupil function:

Image field height [mm]	Actual value [mrad]	Actual-desired [mrad]
63,6	5,32	0,07
57,3	1,59	-0,10
51,0	-0,92	0,04
44,6	-2,64	0,10
38,3	-3,74	0,01
31,9	-4,20	-0,09
25,5	-4,00	-0,08
19,1	-3,30	0,01
12,8	-2,28	0,09
6,4	-1,15	0,09

Table 15

	RADIUS	THICKNESS		248.3	EPS	248.B.
				1.0		1.0
				1.0		1.0
1	**********	45.143				
2	-31.6971	28.136	SUPRA1	1.508366	-.055	1.508088
3	-47.9230	39.292		1.0		1.0
4	428.1252	66.494	SUPRA1	1.508366	-.055	1.508088
5	-150.7305	18.557		1.0		1.0
6	195.9789	44.285	SUPRA1	1.508366	-.055	1.508088
7	471.9253	163.776		1.0		1.0
8	-601.7158	22.837	SUPRA1	1.508366	-.055	1.508088
9	-248.8469	22.518		1.0		1.0
	STOP	.000				
10	**********	16.000		1.0		1.0
11	**********	50.950		1.0		1.0
12	271.7523	46.762	SUPRA1	1.508366	-.055	1.508088
13	-332.7323	16.448		1.0		1.0
14	1632.0761	13.064	SUPRA1	1.508366	-.055	1.508088
15	125.5812	155.737		1.0		1.0
16	**********	357.505		1.0		1.0
17	-406.8452	24.422	SUPRA1	1.508366	-.055	1.508088
18	-176.1262	4.072		1.0		1.0
19	**********	4.000	SUPRA1	1.508366	-.055	1.508088
20	**********	60.000		1.0		1.0
21	**********			1.0		1.0
22	**********	.000		1.0		1.0

Table 10

SURFACE		ASPHERIC CONSTANTS				
5	A	.30700259	.36275241E-07	.14555048E-11	.25367843E-16	.64827842E-21
		.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00
9	A	.01609567	.44063917E-07	.16962313E-11	.81523571E-17	.54237049E-20
		.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00
17	A	-.00048398	.45060462E-07	.70280547E-11	.20097185E-14	.00000000E+00
		.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00
18	A	.00009906	.48624218E-07	.27774765E-10	.49448573E-14	.94856328E-18
		.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00	-.37136823E-22

Table 11

	RADIUS	THICKNESS		248.3	EPS	248.8
1	************	68.529		1.0		1.0
				1.0		1.0
2	-41.3402	37.553	SUPRA1	1.508366	.055	1.508088
3	-65.1683	1.899		1.0		1.0
4	-1821.9029	52.155	SUPRA1	1.508366	.055	1.508088
5	-165.0414	20.937		1.0		1.0
6	277.4757	67.266	SUPRA1	1.508366	.055	1.508088
7	-381.8306	200.731		1.0		1.0
8	************	17.900		1.0		1.0
	STOP	.000				
9	************	19.430		1.0		1.0
10	169.1379	50.513	SUPRA1	1.508366	.055	1.508088
11	-2197.7333	72.898		1.0		1.0
12	350.2263	11.856	SUPRA1	1.508366	.055	1.508088
13	103.0750	128.232		1.0		1.0
14	************	339.584		1.0		1.0
15	-183.2474	21.658	SUPRA1	1.508366	.055	1.508088
16	-114.7171	24.758		1.0		1.0
17	************	4.000	SUPRA1	1.508366	.055	1.508088
18	************	60.000		1.0		1.0
19	************	.000		1.0		1.0
20	************			1.0		1.0

Table 13

ASPHERIC CONSTANTS

SURFACE						
4	A	.00088826	.33072665E-08	.27728125E-12	.66528381E-16	.27747818E-20
			.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00
7	A	.00146323	.23687863E-07	.73089141E-13	.70178044E-17	.17741133E-21
			.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00
11	A	.00013830	.41436721E-07	.16796245E-12	.59248839E-17	.91470033E-22
			.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00
15	A	-.02425149	-.95943615E-07	.10248697E-11	.27847883E-14	.00000000E+00
			.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00
16	A	-.00011652	.37799825E-07	.24137738E-10	.59574191E-14	.12288559E-17
			.00000000E+00	.00000000E+00	.00000000E+00	.59577481E-22

Table 14

RADIUS	THICKNESS	248.3	EPS	248.8
		1.0		1.0
		1.0		1.0
1*************	65.935	1.0		1.0
2 -40.6035	38.487 SUPRA1	1.508366	-.055	1.508088
3 -64.3159	5.680	1.0		1.0
4 1995.7246	53.136 SUPRA1	1.508366	-.055	1.508088
5 -189.7903	26.685	1.0		1.0
6 344.0589	66.052 SUPRA1	1.508366	-.055	1.508088
7 -298.0580	198.231	1.0		1.0
8*************	17.900	1.0		1.0
STOP	.000			
9*************		1.0		1.0
10 182.3714	55.709 SUPRA1	1.508366	.055	1.508088
11 -512.3641	47.471	1.0		1.0
12 700.0127	12.241 SUPRA1	1.508366	.055	1.508088
13 104.1003	149.883.	1.0		1.0
14*************	343.316.	1.0		1.0
15 -184.4560	20.375 SUPRA1	1.508366	.055	1.508088
16 -115.3836	22.308	1.0		1.0
17*************	4.000 SUPRA1	1.508366	.055	1.508088
18*************	60.000	1.0		1.0
19*************	.000	1.0		-1.0
20*************		1.0		1.0

Table 16

ASPHERIC CONSTANTS

SURFACE							
7	A	.00534764	.28361731E-07	-.33416725E-13	-.27596098E-17	.53973409E-22	.00000000E+00
			.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00	
11	A	-.00014610	.39915901E-07	-.39110773E-12	.38577737E-17	.77184766E-22	.00000000E+00
			.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00	
15	A	-.03140665	-.10763439E-06	.40961531E-11	.26507084E-14	.00000000E+00	.00000000E+00
			.00000000E+00	.00000000E+00	.00000000E+00		
16	A	-.00031061	.48775194E-07	-.21584376E-10	.59528473E-14	.12049627E-17	-.59417852E-22
			.00000000E+00	.00000000E+00	.00000000E+00		

Table 17

Table 18

j124o

Sur.No.	Radius	Thickness/Distance	Material	Refr. Index	Fr. Diam.	
0	0	40		1	136	
1	0	0		1	162,238	
2	0	10	SIO2HL	1,56018811	162,238	
3	0	90,00242783		1	166,316	
4	0	126,1714501		1	225,352	
5	284,819283	88,25879422	SIO2HL	1,56018811	346,704	
6	-718,846875	67,94464464		1	344,764	
7	332,99532	29,58650607	SIO2HL	1,56018811	277,8	
8	229,906571	87,36888257		1	252,304	
9	-221,626736	15	SIO2HL	1,56018811	247,846	
10	-858,351043	96,28958137		1	258,722	
11	-223,041108	15	SIO2HL	1,56018811	272,15	
12	-610,039132	43,05996383		1	300,996	
13	-221,235303	15	SIO2HL	1,56018811	303,626	
14	-496,460616	39,93674981		1	353,65	
15	0	0		-1	488,926	REFL
16	261,673247	39,93674981		1	358,9	REFL
17	496,460616	15	SIO2HL	1,56018811	352,086	
18	221,235303	43,05996383		1	294,964	
19	610,039132	15	SIO2HL	1,56018811	288,496	
20	223,041108	96,28958137		1	256,802	
21	858,351043	15	SIO2HL	1,56018811	225,826	
22	221,626736	87,36888257		1	211,74	
23	-229,906571	29,58650607	SIO2HL	1,56018811	209,998	
24	-332,99532	67,94464464		1	221,786	
25	718,846875	88,25879422	SIO2HL	1,56018811	233,566	
26	-284,819283	148,919977		1	231,788	
27	0	117,2478983		1	163,64	
28	0	24,99733735		1	242,922	
29	603,370765	39,04445671	SIO2HL	1,56018811	270,182	
30	-636,597636	0,948767519		1	272,294	
31	342,176859	50,00126936	SIO2HL	1,56018811	277,832	
32	17319,8551	73,84714255		1	272,836	
33	-218,591907	8,99910435	SIO2HL	1,56018811	262,016	
34	904,679885	54,19491053		1	281,338	
35	-680,586753	54,40626463	SIO2HL	1,56018811	299,432	
36	-220,41366	5,817238376		1	305,088	
37	500,62792	15,60974916	SIO2HL	1,56018811	297,022	
38	198,761197	53,16103132		1	282,566	
39	814,404669	36,98819327	SIO2HL	1,56018811	289,582	
40	-871,120646	0,949164971		1	294,484	
41	835,76703	39,91455494	SIO2HL	1,56018811	307,664	
42	-726,054716	0,949236893		1	309,074	
43	317,363233	57,34718751	SIO2HL	1,56018811	309,176	
44	3960,12424	39,5720585		1	301,446	
45	-420,71174	9,499467238	SIO2HL	1,56018811	297,386	

Table 18 (continuation)

46	359,94645	56,65260716		1	
47	-2691,51008	44,96770761	SIO2HL	1,56018811	296,478
48	-306,711407	3,572848114		1	306,182
49	742,794849	27,51408106	SIO2HL	1,56018811	310,034
50	-5522,84952	-0,960213691		1	310,324
51	0	1,905954202		1	309,836
52	286,444693	47,52996513	SIO2HL	1,56018811	308,384
53	2180,55421	0,940628914		1	309,936
54	223,755941	47,20113369	SIO2HL	1,56018811	306,14
55	764,2653	0,937188691		1	282,118
56	142,961746	51,14510511	SIO2HL	1,56018811	273,64
57	594,670868	0,91280099		1	221,778
58	120,817932	25,60552721	SIO2HL	1,56018811	207,25
59	234,539697	0,813496277		1	154,022
60	117,536405	41,01820363	SIO2HL	1,56018811	132,74
61	0	2,00024195	H2OV193	1,43667693	112,148
62	0	-0,00024161		1	40,986
					34,006

Table 19

Aspheres

Sur.No.	K	C1	C2	C3	C4	C5	C6
6	0	1,81054E-09	-2,31090E-14	9,96078E-19	-1,12802E-23	7,07088E-29	-6,95390E-34
12	0	-8,90600E-10	-1,51217E-13	4,88272E-21	8,25531E-23	-2,79550E-27	2,35098E-31
14	0	-3,34713E-09	5,94735E-14	-1,82452E-19	-1,16648E-23	7,22990E-28	-2,74308E-32
17	0	3,34713E-09	-5,94735E-14	1,82452E-19	1,16648E-23	-7,22990E-28	2,74308E-32
19	0	8,90600E-10	1,51217E-13	-4,88272E-21	-8,25531E-23	2,79550E-27	-2,35098E-31
25	0	-1,81054E-09	2,31090E-14	-9,96078E-19	1,12802E-23	-7,07088E-29	6,95390E-34
34	0	-2,09777E-09	-5,69167E-14	-2,08879E-19	3,29541E-23	6,66605E-28	-1,96222E-32
45	0	-7,23645E-09	1,09023E-13	-3,10776E-18	3,84103E-22	-9,66600E-27	-8,74269E-32
47	0	-7,61174E-09	2,65544E-13	-7,37805E-18	3,19143E-22	-2,12393E-26	5,21669E-31
53	0	4,28502E-10	4,33345E-13	-2,08439E-17	2,18135E-22	5,73143E-27	-1,02762E-31
57	0	8,39683E-09	8,08208E-13	-6,65945E-17	5,13258E-21	-3,16949E-25	8,16626E-30
59	0	4,78541E-08	6,68577E-12	-1,88747E-16	-1,54458E-20	1,63093E-23	-1,04350E-27

Table 20

j127o

Sur.No.	Radius	Thickness/distance	Material	Refr. Index	Fr. Diam.	
0	0	40		1	136	
1	0	0		1	162,23	
2	0	10	SIO2HL	1,56018811	162,23	
3	0	90,00136568		1	166,306	
4	0	126,9754212		1	225,326	
5	287,871657	87,61804518	SIO2HL	1,56018811	346,638	
6	-714,813191	72,13214669		1	344,79	
7	332,204484	30,00699117	SIO2HL	1,56018811	277,208	
8	228,934009	86,52185874		1	251,744	
9	-225,793329	15	SIO2HL	1,56018811	247,436	
10	-736,477377	88,69950684		1	257,478	
11	-223,422523	15	SIO2HL	1,56018811	267,924	
12	-670,949887	43,07304995		1	295,618	
13	-220,819788	15	SIO2HL	1,56018811	298,228	
14	-499,016297	39,4948838		1	345,992	
15	0	0		-1	474,852	REFL
16	259,210693	39,4948838		1	351,666	REFL
17	499,016297	15	SIO2HL	1,56018811	344,228	
18	220,819788	43,07304995		1	289,47	
19	670,949887	15	SIO2HL	1,56018811	283,008	
20	223,422523	88,69950684		1	252,278	
21	736,477377	15	SIO2HL	1,56018811	225,524	
22	225,793329	86,52185874		1	212,25	
23	-228,934009	30,00699117	SIO2HL	1,56018811	210,37	
24	-332,204484	72,13214669		1	222,306	
25	714,813191	87,61804518	SIO2HL	1,56018811	234,366	
26	-287,871657	150,4821633		1	232,45	
27	0	116,4962314		1	163,22	
28	0	24,99582853		1	242,07	
29	608,165543	38,78395838	SIO2HL	1,56018811	269,198	
30	-633,325408	0,947612575		1	271,334	
31	344,637109	45,34004131	SIO2HL	1,56018811	276,98	
32	-62952,622	76,39801942		1	273,248	
33	-217,488195	8,998996112	SIO2HL	1,56018811	261,15	
34	996,855971	54,49706951		1	280,182	
35	-688,700451	54,41929128	SIO2HL	1,56018811	298,924	
36	-219,471564	1,418978688		1	304,346	
37	431,058008	15,20870568	SIO2HL	1,56018811	294,528	
38	192,067389	63,01795094		1	278,474	
39	987,105089	32,04274664	SIO2HL	1,56018811	290,984	
40	-891,544249	0,948742302		1	294,704	
41	677,684124	41,63748934	SIO2HL	1,56018811	308,902	
42	-818,475719	0,949203181		1	309,902	
43	325,99568	57,4047341	SIO2HL	1,56018811	307,608	
44	13052,304	36,34195774		1	299,756	
45	-390,220688	9,497543304	SIO2HL	1,56018811	297,718	

Table 20 (continuation)

46	350,704764	54,90641556		1	297,02
47	-2978,76559	46,68826821	SIO2HL	1,56018811	306,046
48	-300,028769	0,944451222		1	310,008
49	871,548118	27,20190252	SIO2HL	1,56018811	310,024
50	-2770,02197	-1,193616306		1	309,682
51	0	2,132719511		1	308,032
52	271,299915	46,98951537	SIO2HL	1,56018811	309,962
53	1226,61461	0,930593484		1	305,892
54	234,802856	49,00464753	SIO2HL	1,56018811	284,866
55	1226,61461	0,922464986		1	276,644
56	137,676807	51,75763941	SIO2HL	1,56018811	217,64
57	542,765286	0,899139131		1	202,58
58	118,289771	24,20432254	SIO2HL	1,56018811	149,71
59	209,420984	0,848851855		1	127,784
60	116,984714	40,14644803	SIO2HL	1,56018811	110,648
61	0	2,000071048	H2OV193	1,43667693	40,976
62	0	-0,00007074		1	34,002

Table 21

Aspheres Sur.No.	K	C1	C2	C3	C4	C5	C6
6	0	1,69174E-09	-2,05881E-14	1,03251E-18	-1,12193E-23	3,90449E-29	-5,29045E-34
12	0	-1,41589E-09	-1,57552E-13	1,25094E-18	2,21664E-23	2,23065E-28	1,88935E-31
14	0	-3,46732E-09	6,26464E-14	-3,07498E-19	-8,03587E-24	6,53890E-28	-3,03891E-32
17	0	3,46732E-09	-6,26464E-14	3,07498E-19	8,03587E-24	-6,53890E-28	3,03891E-32
19	0	1,41589E-09	1,57552E-13	-1,25094E-18	-2,21664E-23	-2,23065E-28	-1,88935E-32
25	0	-1,69174E-09	2,05881E-14	-1,03251E-18	1,12193E-23	-3,90449E-29	5,29045E-34
34	0	-2,08973E-09	-3,21415E-14	-4,89621E-19	4,99266E-23	6,37920E-29	-1,16558E-32
45	0	-9,02991E-09	1,92955E-13	-2,66461E-18	2,63723E-22	-8,86762E-27	-3,54012E-32
47	0	-6,06114E-09	1,64132E-13	-4,22802E-18	1,75836E-22	-1,41128E-26	4,02240E-31
53	0	1,24264E-09	2,65702E-13	-1,73022E-17	2,87349E-22	2,96301E-27	-8,89915E-32
55	0	1,24264E-09	2,65702E-13	-1,73022E-17	2,87349E-22	2,96301E-27	-8,89915E-32
57	0	-2,48214E-09	1,65060E-12	-4,57406E-17	4,60607E-22	-6,08631E-26	2,96024E-30
59	0	6,48548E-08	5,64309E-12	-3,20630E-17	-3,28553E-20	2,51656E-23	-1,95410E-27